to relatively low ^{23}Na concentrations in biological tissues, a rapid bi-exponential signal decay, and a low gyromagnetic ratio. Despite these challenges, recent hardware improvements and novel SNR-efficient pulse sequences have demonstrated feasibility of sodium MR in cartilage *in vivo* in reasonable scan times. However, most of these studies have used small surface coils with limited volume sensitivity. Achieving whole joint coverage with adequate SNR has been difficult.

In this work, we explore the feasibility of whole-knee sodium MR. We present images from a custom sodium-tuned volume coil for whole-knee sodium imaging at 3T, and compare the achieved resolution and image quality with various other surface coil configurations at both 3T and 7T.

Methods: A fast gradient-spoiled sequence using a 3D cones k-space trajectory was developed for sodium image acquisition. The sodium sequence was implemented on both 3T and 7T GE Signa Excite whole-body scanners with HFD gradients (GE Healthcare, Waukesha, WI). A custom sodium-tuned Helmholtz pair coil was developed for use at 3T, with loop diameter of 5 inches and loop separation of 5.25 inches. Surface coils employed in the study include a custom 4 inch sodium-tuned coil at 3T, and a dual-tuned 5 inch surface coil at 7T.

Results: Surface coil configurations were able to achieve excellent SNR across small FOVs at high resolutions in reasonable scan times.

Figure 1 shows axial proton and sodium images of the patellofemoral joint of a healthy 35 year-old volunteer at 7T (1x1x2 mm, 24 min scan time). The axial proton and sodium images from a healthy 65-year-old volunteer show no abnormality on the proton images but lower sodium (and proteoglycan) concentration. The surface coils were placed on top of the patella. Full coverage of the tibiofemoral joint is difficult to obtain with surface coils.

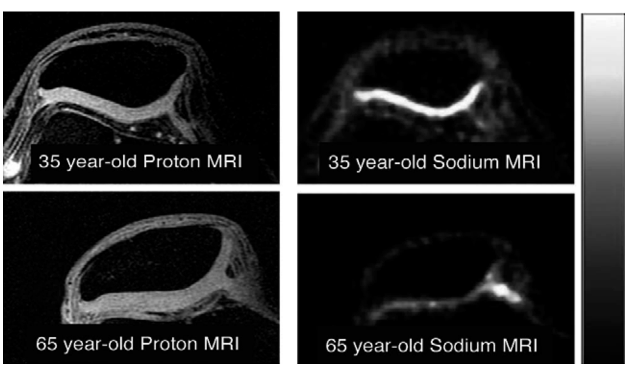

Figure 1

Figure 2 shows a sagittal section near the coil (placed on the lateral surface of the knee) in a healthy volunteer at 3T (1.25x1.25x4mm, 16 min total scan time). While this section shows good SNR, the SNR decreased rapidly for more medial slices.

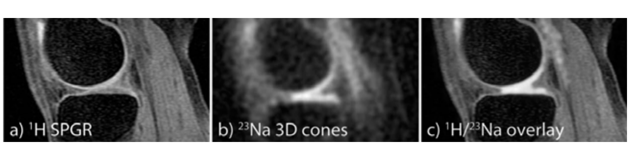

Figure 2

The Helmholtz pair configuration at 3T achieved full-knee coverage with adequate SNR, but at a slightly reduced resolution and increased scan time.

Figure 3 shows several sagittal slices from a normal volunteer using the Helmholtz coil. Resolution was 2x2x4 mm and total scan time was 31 min.

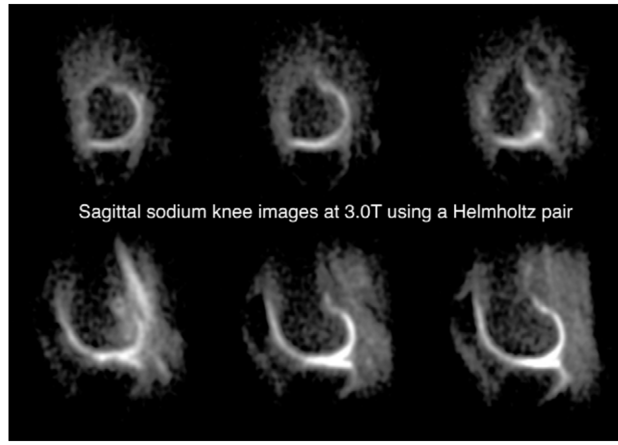

Figure 3

Conclusions: We have demonstrated feasibility of *in vivo* whole-knee sodium MR at reasonable resolutions (2x2x4 mm) at 3T using a Helmholtz coil configuration. Further SNR gains over the Helmholtz configuration can be expected with more advanced coil configurations, such as sodium-tuned phased-arrays. We conclude that further improvements in sodium MR coil design will enable whole-knee *in vivo* sodium MR with adequate SNR and resolution for PG assessment in acceptable scan times.

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REPRODUCIBILITY OF RADIOGRAPHIC ANATOMICAL AXIS MEASUREMENT OF THE KNEE USING A SOFTWARE WORKFLOW TOOL

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Purpose: There is evidence that knee alignment is associated with progression of knee osteoarthritis (KOA). The Anatomic Axis (AA) angle has previously been described as a method for assessing varus and/or valgus in KOA on planar radiographs. A new software tool for performing AA has been developed (KneeAnalyzer™, Optasia Medical) as part of a clinical trials image management solution (Bio-Track™, Bio-Imaging Technologies). The AA measurement is conducted in conjunction with the semi-automated joint-space width measurement of the medial and lateral compartments of the knee.

Methods: The AA measurement is made as an angle formed by the intersection of two lines. The first is defined from the mid-point of the valley between the tibial spines to the mid-point of the cross-section of the tibial shaft 10cm below the tibial spines. The second is taken as the line from the mid-point of this valley to the cross-section of the femoral shaft 10cm above the tibial spines. The angle measurement is then taken on the lateral side of where the lines bisect. 32 patients with KOA (Kellgren-Lawrence grade 2 or 3) had duplicate x-rays taken of the knee, on the same day with repeat positioning, using the Lyon-Schuss fixed flexion acquisition protocol with limb placement standardised utilizing a positioning device (Synaflexer™, Synarc). The images were digitized, and then blinded to patient ID and measurement chronology. Two x-ray technologists were trained in the use of the software tool. Both technologists then applied the AA measurements on all 64 images. All measurements were recorded automatically by the software.

Results: The mean angle (SD) for the technologists were 180.8 (2.98) and 181.2 (2.82) degrees respectively. The SD between the technologists, which provides an estimate of the inter-reader variability if the technologists had no variability in their own esti-

mates, was 0.362 degrees. The intraclass correlation coefficient (ICC) for a single technologist (between image variation) was 0.962 and for between technologists was 0.946.
Conclusions: The AA can be assessed using the workflow software with sufficient precision to be used in clinical trials. The test/re-test variability of AA measurement using this workflow tool assessed as the between image ICC is similar to figures previously reported [1]. AA measurements using such a tool may provide a useful eligibility assessment to make inclusion/exclusion decisions on patients who have excessive varus or valgus during the screening phase of a trial in KOA.

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GAGCEST: ASSESSMENT OF GAG IN CARTILAGE VIA CEST

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Purpose: Characterization of CEST approach in model systems and bovine cartilage
Methods: In 1H NMR spectroscopic analysis (HR-MAS, TOCSY, HSQC) of PG, we identified both amide and hydroxyl protons as possible chemical exchange saturation transfer (CEST) agents. Along with these labile sites, there exist two nuclear Overhauser effect (NOE) induced sites at the upfield of water signal. We distinguish the NOE sites from labile sites upon its different behavior with the existence of bulk D2O. To validate the applicability of CEST on cartilage, the cartilage itself was used to construct z-spectra instead of phantom. A bovine patellar cartilage tissue was then also evaluated ex vivo for gagCEST's ability to detect [GAG] variation on a 3T scanner. The exacted CEST image contrast demonstrates its applicability to detect variation of [GAG].
Results: Both amide and hydroxyl protons were identified using NMR spectroscopy using temperature variation approach. NOE sites and labile sites act similar in the presence of bulk water while opposite in presence of bulk D2O: the labile sites diminish while NOE sites enhanced according the equation:
NOEH2O=T1*Omiga*Iz
Where Iz denotes the magnetization from GAG; Omiga is the cross-relaxation constant between water and GAG. Omiga is negative due to the slow motion of GAG. The CEST effect was demonstrated on z-spectra of cartilage trypsinization series, along with asymmetric plot and CEST vs. [23Na] plot. The CEST results of intact and depleted cartilage samples were consistent with a decrease in [23Na]. The OH based CEST effect is almost linear with [23Na] while NH based CEST shows complications. The amide proton, however, should be further explored due to its uniqueness to GAG species. CEST-enhanced images of bovine cartilage at 3T clinical scanner demonstrate the feasibility of the approach for clinical translation.
Conclusions: 1H MRI with chemical exchange saturation transfer (CEST) proves to be a powerful method for diagnosing the early degenerative changes in cartilage tissue. The CEST based on OH at +1.0ppm downfield to water contrast has been shown to be sensitive to PG concentration. The high efficiency, specificity, and totally non-invasiveness make it a natural choice for many GAG based application.

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DIAGNOSING HAND OSTEOARTHRITIS FROM DIGITAL PHOTOGRAPHS: A REPRODUCIBLE SCORING SYSTEM

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Purpose: To develop a standardised scoring system for the diagnosis of hand OA from high quality hand photographs.
Methods: Participants in the study were randomly selected from those enrolled in the AGES-Reykjavik Study. 160 males and 221 females aged 69-92 participated. A Fuji Finepix 6800 zoom camera was used for all subjects with images taken at 2800x2200 pixels. Dark velvet board with two small central markers was used for hand positioning. The camera was mounted on a tripod at a fixed distance. The hands were placed palm down with the thumbs in moderate abduction and the thumbtips on the central markers and the other fingers slightly separated. All photographs were read by two readers (GPH and HJ).
Ten hand joints on each hand were read for evidence of OA. For practice, photographs were scored repeatedly by the two readers, independently and together. The joints were graded with regards to the visual signs of the presence of OA, such as hard tissue enlargement, deformity and visible soft tissue swelling. For the CMC1 joint, thumb positioning was also taken into account. Each of the 20 joints was classified as having one of the following grades: 0= normal joint with no evidence of hand OA, 1= Mild, some evidence of hand OA but not fulfilling the criteria for definite disease, 2= Definite moderate OA and 3= Severe hand OA. Radiographic results were used to aid the standardization. Subsequently, a consensus score was reached for each joint and a reference photo collection was then composed.
Results: Agreement between observers for assessment of individual joints was only moderate at first, but improved with practice and with the use of reference photographs. Final interobserver Kappa (on/off) values ranged from 0,79-0,88 and the Average Measure Intraclass Correlation Coefficient (ICC) from 0,80-85 for the individual DIP joints. For the PIP joints, the numbers ranged from 0,84-0,97 and 0,78-87, respectively. Kappa on/off for the CMC1 joint was 0,88 and the ICC 0,89. Intraobserver agreement values were slightly higher than the interobserver values. Two point differences in scores were recorded in less than 4% of cases. Spearman's correlation coefficient for aggregate scores was 0.78 (0.81 for females and 0.72 for males).
Conclusions: First results of photographic readings for diagnosing hand OA from the AGES-Reykjavik study show acceptable reproducibility and agreement between observers with the use of a reference photo collection. Hand photography may be useful as a screening tool in population studies.

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DETECTION OF BASIC CALCIUM PHOSPHATE CRYSTALS IN THE SYNOVIAL FLUID OF PATIENTS WITH OSTEOARTHRITIS

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Purpose: Basic calcium phosphate (BCP) crystals are found in up to 70% of osteoarthritic(OA) joints and current data suggests that intra-articular BCP crystals represent a potential therapeutic